SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL STUDIES OF SOME NITROGEN AND SULPHUR CONTAINING HETEROCYCLES

Synopsis

OF THE Ph.D. THESIS TO BE SUBMITTED TO THE

MANGALORE UNIVERSITY

FOR THE AWARD OF THE DEGREE OF

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IN

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By

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SYNOPSIS OF THE THESIS TO BE SUBMITTED TO THE MANGALORE UNIVERSITY

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Title of the Thesis : **Synthesis, Characterization and Biological Studies of Some Nitrogen and Sulphur containing Heterocycles**

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Synopsis

Heterocyclic compounds are inextricably woven into the life processes. Heterocyclic chemistry offers an example of the lack of distinct demarcations; in fact, it pervades the plurality of the other chemical disciplines. The vital interest of the pharmaceutical and agrochemical industries in heterocycles is often connected with their natural occurrence. Synthetic chemistry provides a cornucopia of heterocyclic systems. More than 90% of new drugs contain heterocycles and the interface between chemistry and biology, at which so much new scientific insight, discovery and application is taking place is crossed by heterocyclic compounds[1].

The concept of "privileged medicinal structures or scaffolds", originally introduced by Merck researchers in the course of their work on benzodiazepines, has recently emerged as one of the guiding principles of modern drug discovery. It involves the utilization of molecular frameworks with inherent potential for biological activity. Through appropriate functional group modifications, these scaffolds are capable of providing ligands for a number of functionally and structurally discrete biological receptors[2,3]. In addition, compound libraries designed on the basis of such frameworks exhibit enhanced drug-like properties and result in high-quality leads.

Nitrogen-containing heterocycles are of immense research interest because they are often found as naturally occurring bioactive compounds. The prominence of *N*-heterocycles makes it vital to develop methods to increase their synthetic efficiencies and probe the effects of their modifications on biological efficacy[4]. Nitrogen heterocycles represent a highly important class of compounds, which are widely used in material science, agrochemistry and medicinal chemistry. Therefore, there is continuing interest in the development of convenient, efficient and environmentally benign synthetic methods for the construction of nitrogen-containing heterocycles. Due to its natural abundance, ease of use and promising application in industry, the use of visible light as a driving force for chemical reactions has received considerable attention in the past few years[5]. Nitrogen-containing heterocyclic ring systems had various applications, ranging from vitamins and herbicides to antifungal, antibacterial and anticancer agents[6]. The development of more efficient synthetic procedures has been an ongoing quest.

Pyridine is an important heterocyclic compound and is an integral part of various natural products. There are various medicines containing pyridine ring system being available in the market to combat different human ailments[7]. Pyridine-containing compounds have increasing

importance for medicinal applications as antiviral, anticholinesterase, antimalarial, antimicrobial, antidiabetic and anticancer agents. Pyridine-containing compounds act as ROS1 inhibitors[8], EGFR and HER-2 kinase inhibitors[9], cyclin-dependent kinase (CDK) inhibitor[10], PIM-1 kinase inhibitors[11], VEGF receptor-2[12], NF-κB inhibitors[13] and DHFR inhibitors[14].

Thiazole derivatives are an important class of compounds with a wide range of medical applications including treatment of HIV and HCV infections[15], antitrichomonal activities[16], fungicidal activities[17], CDK2 inhibitors[18], anti-inflammatory, anthelmintic[19], antimicrobial, antifungal[20], antitubercular[21] and antioxidant activities[22].

Different active hybrids based on pyrimidines were introduced to achieve the drug design concept. Some dihydropyridine derivatives that were reported in the literature were potential anticancer agents[23]. Pyrimidines are considered to be important for thyroid drugs, leukemia, agricultural chemicals[24] and also possess several interesting biological activities such as antimicrobial, antitumor[25] and antifungal activities[26].

Thiazolidin-4-one scaffold has great potential in medicinal chemistry and is of interest to scientists in view of its wide spectrum of biological activities. This scaffold is often used for designing small molecules with various biological activities like anti-TB, DNA gyrase inhibitory[27], antioxidant and anticancer[28].

2-Iminothiazolidin-4-one nucleus, is one of the privileged scaffolds in modern medicinal chemistry and is of great pharmaceutical relevance with regard to its potential applications as inhibitors of metalloproteinases[29], COX-2[30], CDK-2[31] and SHP-2[32]. Apart from the pharmacological activities such as antidiabetic, anti-inflammatory, anticonvulsant, antimicrobial and antipsychotic, 2-iminothiazolidin-4-one had been proven to be a molecule of immense therapeutic interest as an anticancer agent and inhibitor of tubulin assembly of the microtubules[33-37].

The benzimidazole ring is considered a key structural element in the aromatic framework for the more effective diamidines, which play an important role in biological activities and DNA binding affinity. However, the structure and rigidity of the linker between the two aromatic amidine fragments are also factors to be considered[38]. Benzimidazole nucleus is an important pharmacophore with unique chemical and biological properties[39-44]. Benzimidazoles had been found to possess neuroprotective[45], anti-inflammatory, antidiabetic, antispasmodic,

antihistaminic, analgesic, antimicrobial, antiproliferative, anti-HIV-RT, antiulcer, anti-TB and COX inhibitor activities[46-55].

1,3,4-Thiadiazole derivatives have shown extensive biological activities, such as anti-inflammatory[56], anticancer[57], antifungal[58], anthelmintic[59] antibacterial[60] and plant growth regulator[61].

Owing to the immense applications of the aforementioned heterocyclic compounds in the biological systems along with their advantage of being biocompatible, it was envisioned to synthesize some heterocyclic derivatives and investigate their biological properties. The present study aims both at developing synthetic procedures to access some heterocyclic derivatives and to investigate their biological or electrochemical applications. The thesis entitled "Synthesis, characterization and biological studies of some nitrogen and sulfur containing heterocycles" has been divided into the following six chapters.

Chapter 1: A brief review on chemistry of various nitrogen and sulphur containing heterocyclic compounds

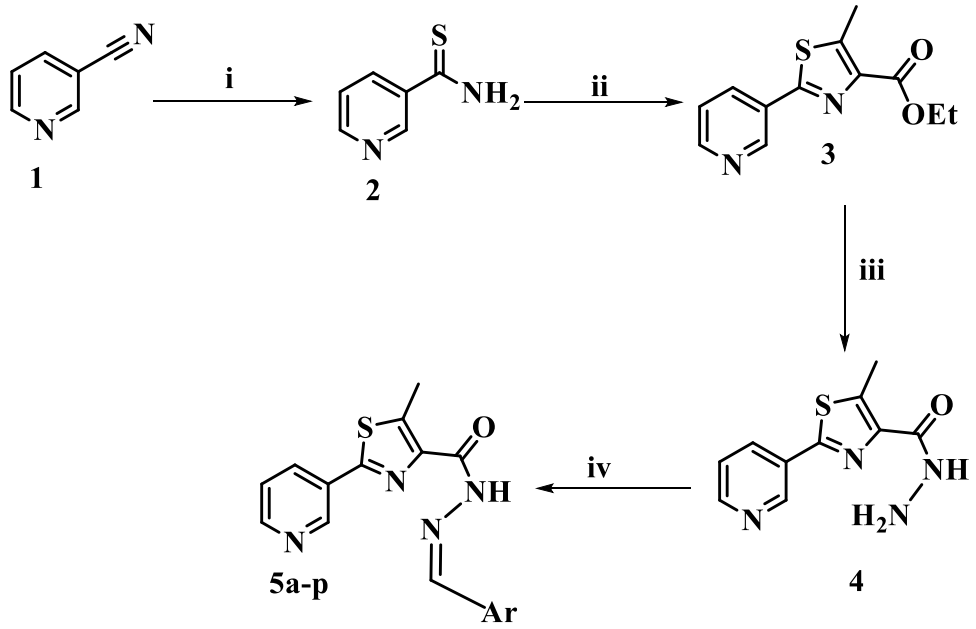
This is an introductory chapter, which deals with a brief account of synthesis and applications of some five and six membered simple and fused heterocyclic derivatives containing nitrogen and sulphur from the publications on chemical literature up to 2022. It mainly deals with strategies for the synthesis of some heterocyclic compounds and their pharmacological applications.

Chapter 2: Synthesis, biological evaluation, DNA binding and docking studies of thiazolyl carbohydrazides

This chapter contains the synthesis and characterization of some thiazole containing carbohydrazides, followed by evaluation of their anti-inflammatory and antimicrobial properties and also DNA binding studies. The synthetic pathway for the preparation of the target compounds **(5a-p)** is outlined in **Scheme 1**. 3-Cyanopyridine was taken as starting material, which was converted to thioamide, **2** on treatment with H_2S gas in presence of triethylamine in absolute alcohol. The resulting thioamide **2** upon reaction with ethyl-2-chloroacetoacetate gave thiazole derivative, **3**. Refluxing compound **3** with hydrazine hydrate resulted the corresponding hydrazide intermediate, **4**. Compounds **5a-p** were obtained by refluxing intermediate **4** with different substituted aldehydes in presence of catalytic amount

of acetic acid in ethanol. The structures of the target compounds were confirmed by elemental analyses, FT-IR, ^{1}H NMR, ^{13}C NMR and mass spectroscopic data.

Synthesized compounds were further screened for their anti-inflammatory activity by denaturation of bovine serum albumin method. Compounds **5j**, **5k**, **5l** and **5o** unveiled significant activity when compared to the standard drug Diclofenac sodium. Minimum Inhibitory Concentrations (MIC) of the carbohydrazide derivatives, against two Gram-positive (*S. aureus* and *B. subtilis*) and two Gram-negative (*E. coli* and *P. aeruginosa*) bacterial strains and fungal strains (*A. flavus, T. atroviridae, P. citranum* and *C. albicans*) were determined to understand their inhibitory effectiveness using Tetracycline and Streptomycin for antibacterial, Fluconazole and Nystatin for antifungal studies as standard drugs. Molecular docking studies revealed the binding interactions of the synthesized compounds with the Cyclooxygenase-2 (COX-2) protein (PDB: 3LN1) displayed effective interactions with amino-acid residues like Gln-178, Ser-339, Arg-499 and Phe-504. All the compounds were tested for their preliminary cytotoxicity by haemolytic assay. In addition, DNA binding studies were also performed. Along with biological studies cyclic voltammetry studies were also carried out to understand the electrochemical properties of the compounds **5a**, **5b**, **5d**, **5g** and **5h**.



Where, Ar = 4-F-Ph, 4-Cl-Ph, 4-Br-Ph, 4-OMe-Ph, 3-NO_2-Ph, 3,4-$(OMe)_2$-Ph, 4-Me-Ph, 4-OH-Ph, 4-Me_2N-Ph, 3,4-Me_2-Ph, 5-Br-2-OH-Ph, 4-OH-3-OMe-Ph, 3-OH-4-OMe-Ph, 4-$PhCH_2$-O-Ph, 2-Furyl, 3-Indolyl.

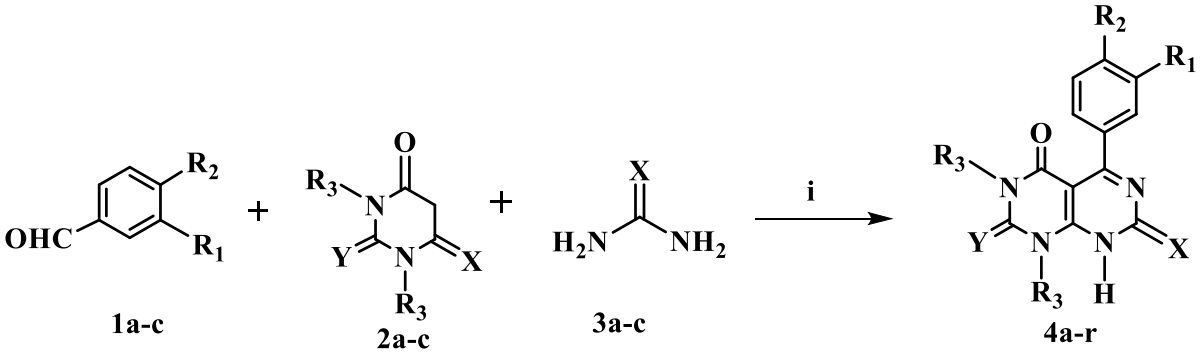
Scheme 1: Synthetic pathway for the preparation of the thiazole containing carbohydrazides

Reagents and conditions: i) EtOH, H_2S, TEA, RT, stirring, 12 h; ii) ethyl-2-chloroacetoactate, EtOH, 70 ℃, 7 h; iii) hydrazine hydrate, EtOH, 90 ℃, 4 h; iv) Ar-CHO, acetic acid (catalytic), EtOH, reflux, 90 ℃, 4 h.

Chapter 3: Dihydropyrimidopyrimidines - Unexpected products in one-pot Biginelli reaction: Design, synthesis, selective cytotoxicity, anti-inflammatory and antimicrobial studies

The synthesis of the title compounds, **4a-r** was drafted in **Scheme 2**. Aldehyde, thiourea/urea/guanidine hydrochloride and barbituric acid/1,3-dimethylbarbituric acid were taken as starting materials and converted to dihydropyrimidopyrimidines (**4a-r**) in presence of ceric ammonium nitrate (CAN) in water : ethanol (8:2, v/v). Formation of the compounds was confirmed on the evidence of elemental analysis, FT-IR, ^{1}H NMR, ^{13}C NMR and mass spectroscopic data.

The newly synthesized compounds with anti-inflammatory and antimicrobial effectiveness were screened for their anticancer activity against MCF-7 and A-549 cell lines and highly potent compounds **4j** and **4k** were screened against non-cancerous HEK293 cell. Results obtained from the study revealed that, neither compound **4j** nor **4k** is harmful for non-cancerous HEK293 cells, however, both the compounds showed significant decrease in cell viability. Further, the interactions of compounds with the protein were examined by molecular docking study.



Where, X = O, S, NH; R_1= H, OH, OCH_2Ph; R_2=H, OCH_3, OCH_2Ph; R_3=H, CH_3, Y = O, S.

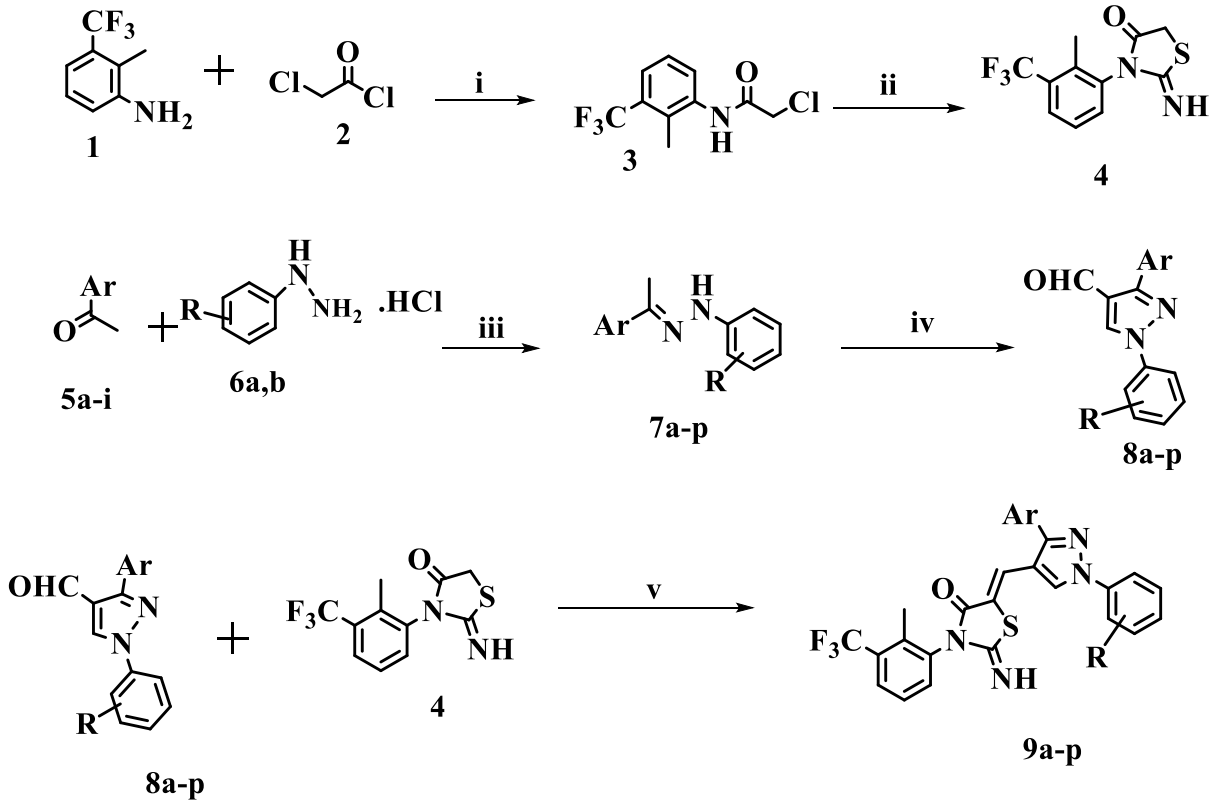
Scheme 2: Synthetic pathway for the preparation of the dihydropyrimidopyrimidine derivatives

Reagents and conditions: i) CAN, EtOH, RT, stirring, 3 h.

Chapter 4: Design, synthesis and biological evaluation of pyrazole embedded thiazolidin-4-one hybrids

The synthesis of the objective compounds, **9a-p** was outlined in **Scheme 3**. 2-Methyl-3-trifluoromethyl aniline (**1**) was treated with chloroacetyl chloride (**2**) in presence of K_2CO_3 in toluene. Intermediate product **3** obtained was treated with KSCN in dry acetone to afford 2-imino-thiazolidin-4-one derivative, **4**. On the other hand, various substituted acetophenones, **5a-i** were treated with two substituted phenylhydrazines, **6a**,**b** with catalytic amount of acetic acid in methanol medium to afford **7a-p**, which on further treatment with Vilsmeier-Haack reagent ($POCl_3$ in DMF) yielded pyrazole aldehydes **(8a-p)**. Finally, desired compounds were synthesized by the treatment of intermediate **4** with **8a-p** in methanol medium using NaOH. All structures of the products were confirmed on the evidence of elemental analysis, FT-IR, ^{1}H NMR, ^{13}C NMR and mass spectroscopic data.

All compounds were tested for their anti-inflammatory activity. They exhibited moderate to good activity. Alongside, the conjugates were analyzed for their *in vitro* antimycobacterial activity. The compounds **8a**, **8c**, **8d**, **8e** and **8f** emerged as potent anti-tubercular and **8a**, **8b**, **8c**, **8h**, **8i** and **8n** emerged as most active anti-inflammatory agents in the series. The *in vitro* cytotoxicity study of the synthesized conjugates against a normal Vero cell line was evaluated and all the potent anti-tubercular molecules such as **8a**, **8c**, **8d**, **8e** and **8f** exhibited low toxicity. Binding pattern of the significantly active compound, **8a** was determined by the docking studies. Further, stability, confirmation and intermolecular interactions with the ligand molecules in the enoyl reductase target were determined by molecular dynamics simulation.



Where R = C_6H_5, 3-Br-C_6H_4, 4-Br-C_6H_4, 4-Cl-C_6H_4, 4-F-C_6H_4, 4-CH_3-C_6H_4, 4-OCH_3-C_6H_4, 3-thienyl; R_1 = H, Cl.

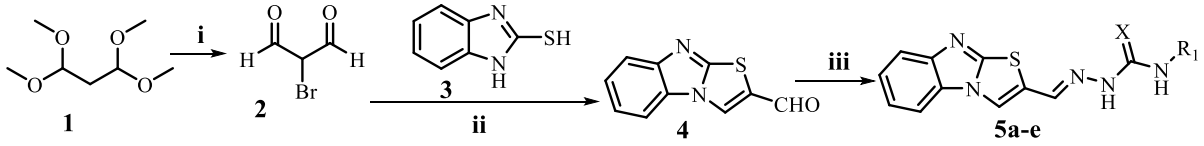
Scheme 3: Synthetic pathway for the preparation of thiazolidin-4-one derivatives

Reagents and conditions: i) K_2CO_3, Toluene, stirring, RT, 6 h; ii) KSCN, dry acetone, reflux, 16 h, 50 ℃; iii) Acetic acid, MeOH, stirring, RT, 1 h; iv) DMF, $POCl_3$, 8 h, 70 ℃; v) NaOH, MeOH, reflux, 6 h, 60 ℃.

Chapter 5: Synthesis and biological evaluation of benzimidazole containing tricyclic systems

The synthesis of benzimidazole containing tricyclic systems was designed and synthesized as drafted in **Schemes 4** and **5**. 1,1,3,3-Tetramethoxypropane (**1**) was converted to bromomalonaldehyde (**2**) using HCl/Br_2. Resulting product obtained was treated with 2-mercaptobenzimidazole (**3**) to give benzo[4,5]imidazo[2,1-*b*]thiazole-2-carbaldehyde (**4**). Further, benzo[4,5]imidazo[2,1-*b*]thiazole-2-carbaldehyde (**4**) was reacted with semicarbazide/thiosemicarbazide, aryl hydrazides, aryl ketones and anilines to give corresponding semicarbazone/thiosemicarbazone, aryl hydrazones, chalcones and Schiff bases respectively.

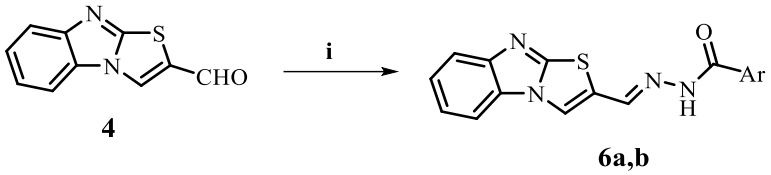
The structures of the newly synthesized compounds were confirmed on the basis of elemental analysis, FT-IR, ^{1}H NMR, ^{13}C NMR and mass spectroscopic data. These compounds were further evaluated for their anti-inflammatory property by denaturation of bovine serum albumin method. Compounds **6c**, **7a** and **9e** exhibited potent anti-inflammatory activity. Antimicrobial screening against *S. aureus*, *B. subtilis*, *E. coli*, *P. aeruginosa*, *A. flavus*, and *C. albicans* was carried out and compound **7b** displayed significant antimicrobial potency against all the tested strains among the series. All the compounds were also tested for their preliminary cytotoxicity by haemolytic assay and found that all the active compounds were non-toxic. Further, the binding interactions of compounds with the protein clorobiocin (PDB code: 1KZN) were examined by molecular docking study.



R_1 = H, Me, Et, Ph; X = O, S.

Reagents and conditions: i) HCl/Br_2, RT, stirring, 1 h; ii) Dry acetone, stirring, RT, 12 h; iii) Semicarbazides/Thisemicarbazides, acetic acid, ethanol, reflux, 60 °C, 4 h.

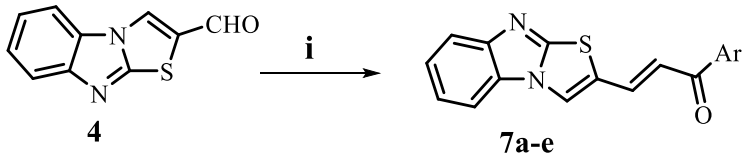
Scheme 4: Synthetic pathway for the preparation of semicarbazones of benzimidazole containing tricyclic system



Ar =Ph, 4-OMe-Ph

Reagents and conditions: i) Sub. benzhydrazide, acetic acid, ethanol, reflux, 60 °C, 4 h

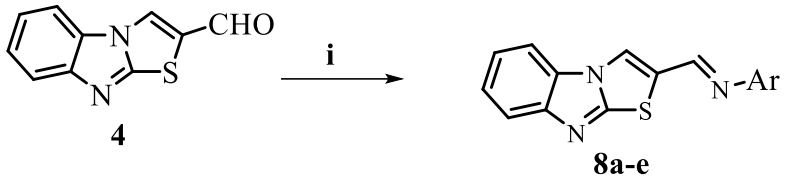
Scheme 5: Synthetic pathway for the preparation of hydrazones of benzimidazole containing tricyclic system



Ar =Ph, 4-Cl-Ph, 4-Br-Ph,4-Me-Ph, 4-OMe-Ph

Reagents and conditions: i) KOH, substituted ketones, ethanol, stirring, RT, overnight

Scheme 6: Synthetic pathway for the preparation of chalcones of benzimidazole containing tricyclic system



Ar =Ph, 4-Cl-Ph, 4-Br-Ph, 4-Me-Ph, 4-OMe-Ph

Reagents and conditions: i) Sub. anilines, acetic acid, ethanol, reflux, 60 °C, 4 h

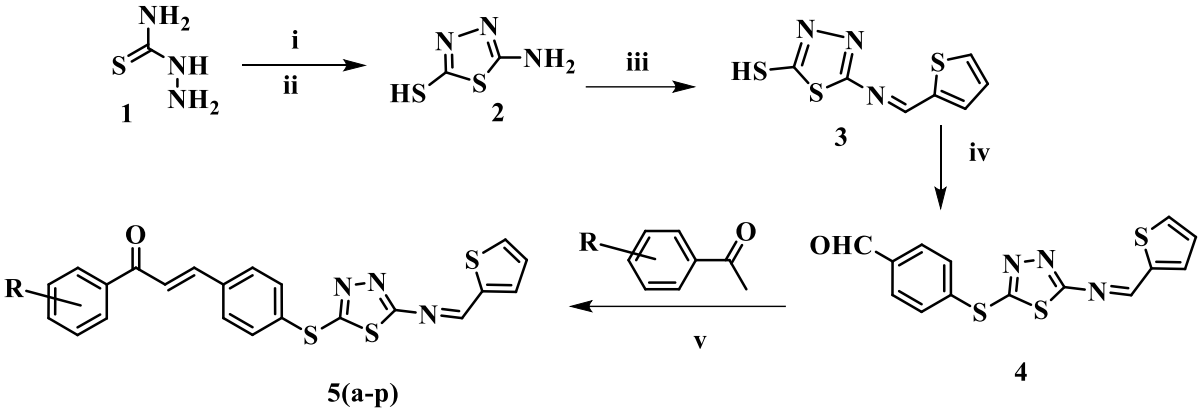
Scheme 7: Synthetic pathway for the preparation of Schiff bases of benzimidazole containing tricyclic system

Chapter 6: Design, facile synthesis and biological studies of 1,3,4-thiadiazole linked chalcones *via* sulfur bridge

This chapter includes the synthesis and characterization of some 1,3,4-thiadiazole linked chalcones followed by anti-inflammatory, antibacterial and antioxidant studies. The synthetic route for the preparation of the objective compounds, **5a-p** was drafted in **Scheme 6**. 5-Amino[1,3,4]thiadiazole-2-thiol (**2**) was synthesized by condensing carbon disulfide with thiosemicarbazide (**1**) under basic condition. Obtained 5-amino[1,3,4]thiadiazole-2-thiol (**2**) was treated with thiophene-2-carboxaldehyde in presence of acetic acid in ethanol to afford the corresponding Schiff base (**3**). The resulting Schiff base (**3)**, on treatment with 4-fluorobenzaldehyde yielded an intermediate aldehyde **4**. Finally, objective chalcone derivatives **5a-p** were obtained by the reaction of intermediate **4** with various substituted ketones in presence of potassium hydroxide in ethanol.

Spectral characterization and elemental analyses data have given justification for the formation of new compounds. Additionally, the antibacterial effectiveness of the synthesized molecules (**5a-p**) was analyzed against Gram-negative and Gram-positive strains by percentage inhibition method. Among the synthesized chalcones, compounds **5g**, **5h** and **5i** emerged as good growth inhibitors of all tested bacterial strains. Compounds **5j**, **5k**, 5**l** and **5o** displayed excellent anti-

inflammatory activity as well. Interestingly, compounds **5c**, **5d**, **5g** and **5j** displayed highest antioxidant capacity.



Where, R = 4-H-C_6H_4, 4-Br-C_6H_4, 4-Cl-C_6H_4, 4-F-C_6H_4, 4-Me-C_6H_4, 4-NH_2-C_6H_4, 4-OH-C_6H_4, 4-NO_2-C_6H_4, 4-OMe-C_6H_4, 3-NO_2-C_6H_4, 2-Cl-C_6H_4, 2,4-OH-C_6H_3, 2,4-Cl-C_6H_3, 3-NH_2-C_6H_4, 3-Br-C_6H_4, 3,5-F-C_6H_3,

Scheme 8: Synthetic pathway for the preparation of 1,3,4 thiadiazole linked chalcones.

Reagents and conditions: i) Na_2CO_3, EtOH, RT, stirring, 10 minutes; ii) CS_2, reflux, 60 ℃, 4 h; iii) Thiophene 2-carboxaldehyde, acetic acid (catalytic), EtOH, reflux, 60 ℃, 4 h; iv) 4-Fluorobenzaldehyde, K_2CO_3, EtOH, 60 ℃, 12 h; v) Alc. KOH, stirring, RT, 12 h.

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List of publications

A. Papers published/accepted/communicated in National/International Journals

1. **Vinuta Kamat**, Suresh P. Nayak, Ganesh Adiga, Aminath Rajeena C. H., Saptami U. Kanekar and Rekha P. D., Design, Facile synthesis and pharmacological evaluation of hybrid 1,3,4-thiadiazole linked chalcone confined *via* sulphur bridge, *Heterocyclic Letters* **2018**, 8, 671-678.

2. **Vinuta Kamat**, Santosh R. and Suresh P. Nayak, (*E*)-*N'*-(4-Fluorobenzylidene)-5-methyl-2-(pyridin-3-yl)thiazole-4-carbohydrazide, *Molbank 2019,* **2019**, *2*, M1058.

3. **Vinuta Kamat**, Rangappa Santosh, Boja Poojary, Suresh P. Nayak, Banoth Karan Kumar, Murugesan Sankaranarayanan, Faheem, Sheela Khanapure, Delicia Avilla Barretto and Shyam K. Vootla, Pyridine- and thiazole-based hydrazides with promising anti-inflammatory and antimicrobial activities along with their *in silico* studies, *ACS Omega* **2020**, *39*(*5*), 25228-25239.

4. **Vinuta Kamat**, Basappa C. Yallur, Boja Poojary, Veerabhadragouda B. Patil, Suresh P. Nayak, Murali Krishna P. and Shrinivas D. Joshi, Synthesis, molecular docking, antibacterial and anti-inflammatory activities of benzimidazole containing tricyclic systems, *J. Chin. Chem. Soc.* **2021**, *68*(*6*), 1055-1066.

5. Aminath Rajeena C. H., Suresh P. Nayak, Ganesh G., **Vinuta Kamat**, B. C. Revanasiddappa and Hemanth Kumar, Synthesis and evaluation of chalcones carrying

1,2,3-triazole moiety for antibacterial and antioxidant activity, *Heterocyclic Letters* **2018**, *8*, 49-59.

6. Aminath Rajeena C. H., Suresh P. Nayak, **Vinuta Kamat**, Revanasiddappa B. C. and Hemanth Kumar, Synthesis, characterization and antibacterial evaluation of chalcones carrying arylfuran moiety, *J. Chem. Pharm. Res.* **2018**, *10*(*6*), 184-189.

7. Divyaraj Puthran, Boja Poojary, Nikil Purushotham, Nandam Harikrishna, Soukhyarani Gopal Nayak and **Vinuta Kamat**, Synthesis of novel Schiff bases using 2-amino-5-(3-fluoro-4-methoxyphenyl)thiophene-3-carbonitrile and 1,3-disubstituted pyrazole-4-carboxaldehyde derivatives and their antimicrobial activity, *Heliyon* **2019**, *5*, 02233.

8. Soukhyarani Gopal Nayak, Boja Poojary, **Vinuta Kamat** and Divyaraj Puthran, Novel thiazolidin-4-one clubbed thiophene derivatives *via* Gewald synthesis as anti-tubercular and anti-inflammatory agents, *J. Chin. Chem. Soc.* **2021**, *68*(*6*), 1116-1127.

9. Soukhyarani G. Nayak, Boja Poojary and **Vinuta Kamat**, Novel Pyrazole-clubbed thiophene derivatives *via* Gewald synthesis as antibacterial and anti-inflammatory agents, *Arch. Der Pharm*. **2020**, *353*(*12*), 2000103.

10. Vinayak Adimule, Basappa C. Yallur, **Vinuta Kamat** and Murali Krishna P., Characterization studies of novel series of Cobalt (II), Nickel (II) and Copper (II) Complexes: DNA binding and antibacterial activity, *J. Pharm. Investig.* **2021**, *51*(*3*), 347-359.

11. Aminath Rajeena C. H., **Vinuta Kamat**, Veerabhadragouda B. Patil, Suresh P. Nayak, Sheela Khanapure, Delicia Avilla Barretto and Shyam K. Vootla, Synthesis and antibacterial evaluation of pyrazolines carrying (benzyloxy)benzaldehyde moiety, *J. Iran. Chem. Soc.* **2021**, DOI: org/10.1007/s13738-021-02403-9.

B. Papers presented in National/International Conference

1. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization and biological evaluation of chalcone based thiadiazole derivatives, presented at two days National level symposium held on 11th and 12th August 2017 at Manipal Institute of Technology, Manipal.
2. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization of thiazolidine-2,4-dione based Mannich base analogs, presented at two days National conference on "Reaching the

unreaching through science and technology: Recent advances in physical, chemical mathematical and biological sciences for energy health and environment" held on 8th and 9th September 2017 at Mangalore University.

3. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization of thiazole containing hydrazone derivatives and their pharmacological screening, presented at three days International conference on "Current Concepts on the role of Indian medicine and phytoceuticals in maintenance of health" and 39th Annual Conference of Indian Association of Biomedical Scientists, held on 15th to17th November 2018 at Jnana Kaveri, Chikka Aluvara Kodagu, Karnataka, India.
4. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization of substituted pyrimidines and their biological studies, presented at two days National conference on "Synthetic, Spectroscopic and Structural Chemistry (SSSC-2019)" held on 15th and 16th March 2019 at Govinda Dasa College Surathkal, Dakshina Kannada, Karnataka, India.
5. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization of tetrahydropyrimidine derivatives and their biological studies, presented at three days International conference on "Advanced Functional Materials for Energy, Environment and Health Care (AFMEEHC)" held on 18th to 20th March 2019 at Vijnana Bhavan Manasagangothri, Mysuru, Karnataka, India.
6. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization of thiazole based hydrazides as multipurpose drugs, presented at three days International conference on "Advances in Chemical and Material science (ICCM-2019)" held on 17th to 19th October 2019 at Mangalore university, Mangalore, Karnataka, India.
7. **Vinuta Kamat** and Suresh P. Nayak, Synthesis, characterization, and antioxidant studies of benzo[4,5]imidazole[2,1-*b*]thiazole-2-carbaldehyde derivatives, presented at three days International conference on "Life, Chemical, and Health Sciences (IcLchs)" held on 24th to 26th October 2019 at Ramaiah College of Arts, Sciences & Commerce, Bangalore, Karnataka, India.

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